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Improving the usability and security of mail-in ballots

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ABSTRACT
While more prevalent than ever, absentee ballots and protocols for them have changed little over the last decades. This paper describes opportunities for improving the accuracy, security but and especially accessibility & usability of paper ballot use for absentee ballots. The approaches focus on adding graphical methods and overlays to help voters be systematic and aware of their selections as they are making them. Our proposals include stickers to show voters how many selections can be made and where, foldable envelopes that allows a user to slide their ballot through a viewing area in an organised way and auditing techniques to improve integrity of the election as well. These proposals address ways of reducing voting errors including for people with reading disabilities, short term memory problems, or motor difficulties.

Author Keywords
Voting, Mail-in ballots, universal design, accessibility

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INTRODUCTION
In the US, mail-in ballots have been responsible for a higher percentage of lost votes than in-person voting and can compromise security and independent and private voting. Error frequency for mail-in ballots is multiple times that of ballots marked and scanned by the voters in a polling place [23]. The chain of custody for a ballot is difficult to establish within a voter's home or in-transit to and from the election office. Independent and private voting is also of concern as others might coerce a voter in filling out their ballot. Early in the Covid-19 pandemic, the prospect of people congregating at polling places deterred electors and election officials; mail-in voting simplified and helped elections to go forward. Many elections where this approach was unavailable were postponed — such as municipal elections in France or parliamentary ones in Sri Lanka. Where the elections were in person — such as in Serbia — the health impact was severe [16]. With the increasing reliance on mail-in ballots, it seems critical to focus on usability improvements that can reduce voter mistakes. Direct Record Electronic[1] (DRE) voting machines improved usability, especially for voters with disabilities (such as visual impairments, tremors, reading disabilities and or short-term memory problems [18]), who have a higher number of issues when voting [1]. Although poor user interface design can mislead voters into not succeeding at casting a vote for a given race [22, 1], well-designed systems can reduce the error rate when compared to paper ballots[20]. Moreover, the availability of redundant systems (such as audio interfaces) can make them both more accessible to visually impaired voters, and improve the voters' privacy.

Inspired by lessons learned for aiding people voting with displays and disabilities, this paper proposes improvements to absentee paper ballot design. Our hypothesis is that paper ballots could learn from the structuring and feedback of DRE user experiences, based on the use of these principles to reduce errors dramatically in voting usability research. Simple tricks such as lining up the votes with a ruler could follow the practice used by people with reading disabilities to improve reading. This could be especially effective when used in conjunction with magnifiers[2] [4]. If such a system is free standing it can also help people with hand tremor as well. While sending each person a structuring and magnifying voting prosthetic might be helpful, there also exists some simpler design changes that can reduce perceptual and memory demands for filling out and verifying one's selections on paper ballots.

OBSERVED ISSUES
This section is devoted to an analysis of issues observed in different mail-in ballot systems around the world. What follows motivated the work and also includes problems that target general paper ballot systems. Our goal here is to obtain a partial list of constraints to keep in mind, as improving certain aspects can create new issues and trade-offs. For example, improving security and accuracy can come with a usability cost. We finish the

[1] Like mail-in ballots, DREs have been decried for their vulnerabilities, especially through hacking, but those considerations are beyond the purview of this paper.
[2] For one such example check https://store.inclusionsolutions.com/ballotmag-magnifier-p217.aspx.

section with a list of objectives that we will then try to attain with the ideas in the following sections.

Accuracy and usability problems

Accuracy problems arise in at least two different contexts. First, the voters themselves make mistakes when filling in their ballot. For example, when faced with long lists of candidates, about 0.4% of the vote supposed to go to top candidates end up for the other candidates just above or below them on the ballot [21]. Voters undervote, sometimes missing a race altogether, or overvote, which can lead to their ballot being voided as they have not selected the correct number of candidates for a given race. These mistakes arise for many reasons, but ballot design plays a large role, as shown with the famously massive undervote in one race in the Sarasota County, Florida, election[3] in 2004 [11].

Folds in paper ballots can reportedly lead to both undervote and overvote. Election officials have complained about folds fouling ballot counting machines and optical scanning. There has also been concern that selections that are close to a fold would be missed. Smoothing out ballots is problematic as manipulating uncounted ballots allows the introduction of errors [4]. Such accuracy issues seem to be compounded in complex ballots[5] such as ballots where voters are asked to rank or rate candidates[6].

Those concerns are also amplified in the context of disabled people , especially visually or cognitively impaired voters. Many solutions have been devised to improve polling place accessibility, with DREs offering variable font size and contrast, audio controls and audits, as well as different low-tech solutions for paper ballots [6], such as magnifying set-ups [19]. On that front, increased availability of mail-in ballots has been seen as a mixed blessing by disability activists and security experts as well. Although it lowers the cost of voting for those with physical disabilities, DRE voting on personal computers or devices has not yet been perfected. Disabled voters are entitled to voting independently, and requiring assistance to fill mail-in ballots is not equal access relative to the the ADA law in the USA, and not acceptable to many blind voters [13, 12].

Counting ballots might be simple in appearance but multiple recounts typically disagree by small margins. This can be due to new ballots being found[7], errors being introduced when viewing or transcribing results, or when announcing them. Disagreements over whether certain ballots are admissible or spoiled require non-trivial adjudication. Finally, there can be fraud where people purposely miscount or add marks to existing ballots[8].

To note, this applies both with Direct Electronic Recording voting machines (DRE) and with paper ballots. Even simple systems with multiple redundancies haven't entirely eliminated mistakes and malfeasance [5][9]. Scanning ballots also affects this, as the proportion of residuals[10] in the USA typically varies by 0.5% between polling places where voters scan their own ballots and facilities where ballots are centralised and scanned [1, 22].

Security problems

The second set of issues with mail-in ballots lies in their security. Unlike polling places where the ballot custody is monitored and contained within a physical space, mail-in ballots present challenges to trusted chains of custody [2]. Having people vote from home exposes the system to two different kinds of risk. First, there is the risk that the wrong ballot or no ballot is sent to the voter. The ballot can be misprinted, delayed during transit or intercepted. These interceptions can lead to multiple negative consequences, most importantly breaching the integrity of the vote by changing the ballot, and breaching the privacy of the voter by finding how they voted. This can be addressed in several ways, with oversight in ballot printing and mailing being essential. Tracking systems through identifiable marks on the ballots or the envelopes is be useful, but this can also be used to breach voter privacy depending on how it's used (especially if

[3] A poorly designed ballot caused 13% of voters to miss voting for the second race on the ballot: congressional race 13 in Sarasota, Florida. The two person race was "hidden" at the top of the second page just above a large headline indicating State races. In the same election cycle, similar issues in the Attorney General race in Charlotte, Lee, and Sumter caused an undervote above 20% [14].

[4] A person fixing ballots might mark it or spoil it.

[5] Even in ballots with a single race, many factors can influence voter accuracy: priming effects, layout, confusing or verbose language, or even having many candidates, or some with famous names.

[6] Such ballots seem especially complex to voters, maybe due to lack of familiarity with a sophisticated or new selection approach — but it might not be the only reason — and this argument is often used when debating complex voting systems.

[7] The first author has personally been in an LA polling place's counting room when a lost ballot box was found behind a door; it had to be airlifted to be counted that election night.

[8] The first author has personally witnessed officials reviewing ballots in private with access to writing instruments, in Wellesley and Arlington MA.

[9] The study cited analyses the French ballot system for presidential elections (in a comparative study with local DREs). It is simple, with a single race, and instead of putting a checkmark for the candidate of their choice, voters take a piece of paper with the name of the candidate and insert it into an envelope (while in a privacy booth). They then must sign the voter rolls as they insert the envelope in the ballot box. The multiple checks at each step also happen with the counting, with the name on each ballot being read out and checked by two different officials, under supervision of representatives from the different parties. Despite those redundancies, errors still happen: the study found discrepancies between the number of votes cast and the number of signatures on voter rolls, averaging between 0.08% and 0.32% when using paper ballots, with errors reported in 9.7% of polling offices.

[10] Residual votes correspond to the proportion of overvotes (making more than the allowed number of selections) and undervotes (not making selections for every race), which vary by jurisdiction and technology used. Percentage of Residual votes are often used to analyse effects of technological change.

the people organising the vote are corruptible) [9]. Security and privacy issues are the most common arguments against mail-in ballots in political debates, even with little evidence of large-scale mail-in ballot fraud [25].

A second issue, is the lack of privacy and risk of coercion within one's home. If the ballot is sent to a home, inhabitants can be tempted to commit voting fraud by voting for their a family member who is unwilling or unable to. The concern of household members coercing each other into voting in a particular fashion has been persistent[11]. While a polling place affords better privacy, coercion is still a possibility, and nursing homes in the USA have also had a problem of supplying ballots that appear to all be identically filled out with voter assistance [7].

Goals

We can use and expand the terminology from [17] and apply it to the mail-in ballot problem. Discarding questions of *verifiability*, we focus on their three components of *integrity*, and add a first one, necessary for the others.

Printed and delivered correctly

is the first compound step, and corresponds to making sure ballots are created and delivered correctly. This includes the correction of the following steps: laying out a ballot with appropriate candidates ; having it printed correctly ; having it delivered to the mailing agent with no loss ; having it addressed and then sent without being delayed or lost, either in transit or at delivery.

Cast as intended

is the second step, and corresponds to making sure that the ballot that is sent indeed corresponds to the voter's wish. Echoing the earlier issues, this means avoiding undervote and overvote by making sure that people vote for the correct number of selections for each race. It also means making sure that the voter chooses accurately, without the problems mentioned above, which mostly depends on usability. Finally, any mechanism we can include to prevent voter coercion in their home is important.

Recorded as cast

is the third step, and means that the ballots must arrive to the counting/polling office as they were cast. This might include packaging the ballot correctly, potentially with an authenticating seal — such as a signature — on an outside envelope, and ensuring that the envelope arrives to the counting office while preventing an adversary from intercepting and replacing, modifying or removing ballots while they are in transit. It must also not be possible to add unauthorised ballots. Moreover, if any tracking method is used to protect the ballots in transit, this must also prevent the possibility of breaching voter secrecy without at least controlling a major part of the voting and postal infrastructure. This objective concerns all the methods that have an effect while the ballot is in transit.

Counted as recorded

is the fourth step, and ensures that the total as reported by the counting office is indeed the sum of all valid ballots. However, in various jurisdictions, many reasons can be used to throw out a ballot[12] Moreover, as stated above, although the error margins are low, hand-counting is hardly devoid from errors in practice, even with triple-checks [5]. This concerns all the auditing and tracking techniques used in counting offices to remove the possibility for this kind of error or fraud. As an additional consideration is the *legitimacy* of the system. Mail-in ballots have stoked fears about the possibility of fraud, which could be as detrimental as actual fraud, as it erodes confidence in elections [8].

IMPROVEMENTS

We here propose ideas that could be used, independently or in concert, to improve different aspects of mail-in voting. We describe multiple options that could lead to improvements in paper ballots and serve further developments.

Envelope improvements

The envelopes themselves can become usability tools to help voters vote privately, navigate the mail-in ballot, and be more accurate while filling it. Here are three examples of how this could be done.

Focusing mechanisms.

To help voters focus on a single race, a sliding ballot holder could be included, as shown on Figure 1, or could be made from the envelope itself.

As an alternative, part of the envelope could also be either transparent or removable, as is shown on Figure 4. This would be especially helpful when using a single race per fold — as proposed below. To help visually impaired people, the transparent segment could be a Fresnel lens, as on Figure 2. While this could remain relatively inexpensive, it does complicate the printing and mailing processes and raises costs.

Modesty panels.

The closing folds of the envelope itself can be used to afford improvement to privacy to improve independent voting an help reduce possibility of coercion by people during the process. The ballot and envelope can be designed to allow a voter to conceal the area the voter is

[11] For an example from the early 20th century, the French communists' reluctance to give women the right to vote was linked to a fear that they would follow the will of their husband or priest at the polling station, which would add votes for conservative parties [10].

[12] In the election following Katrina, thousands of ballots without notary stamps cast by displaced people from New Orleans were thrown out. The election board included the following list of reasons for rejections attached to the box of rejected ballots: being signed but not with a witness or notary; including only one witness and no notary; with two witnesses but not signed; not being signed at all; having voted more than once; having no affidavit; not casting a vote; having distinguishing marks; being a duplicate ballot; using the wrong ballot; or voting for more than one candidate.

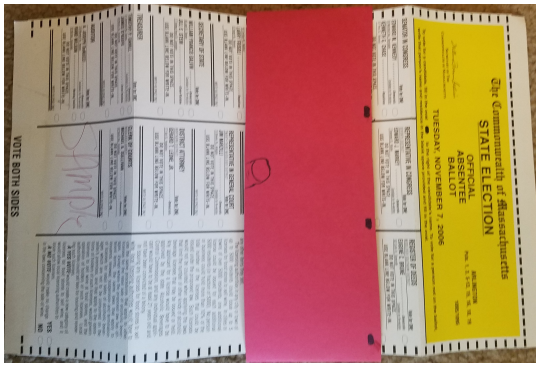

Figure 1. An example of sliding ballot holder. The voter makes it move along the ballot, and it helps align the races one by one to improve usability and reduce over-vote and undervote. This might be especially helpful for people with reading disabilities, tremors, sight problems, or short-term memory problems.

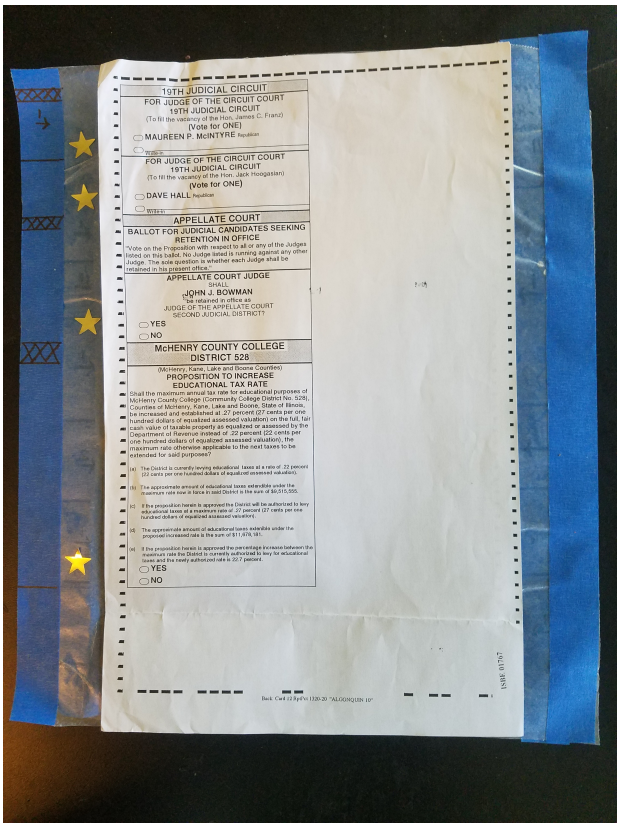

Figure 3. A ballot with added stickers on the side. The nonstick paper makes it easier to peel them out, and the indicators next to them allow voters to quickly check which races they haven't voted on yet.

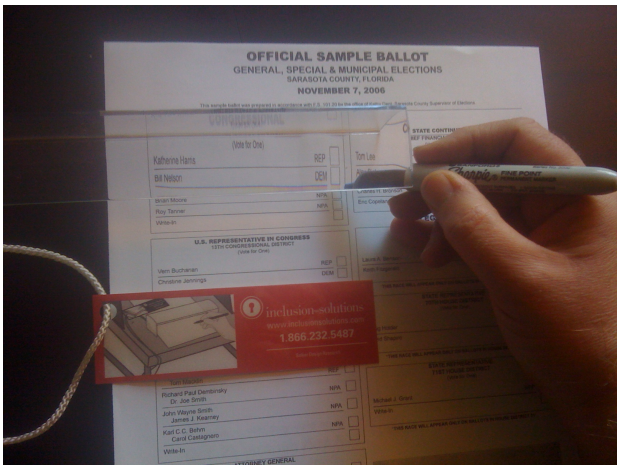

Figure 2. An example of inexpensive pocket magnifier already proposed for polling places.

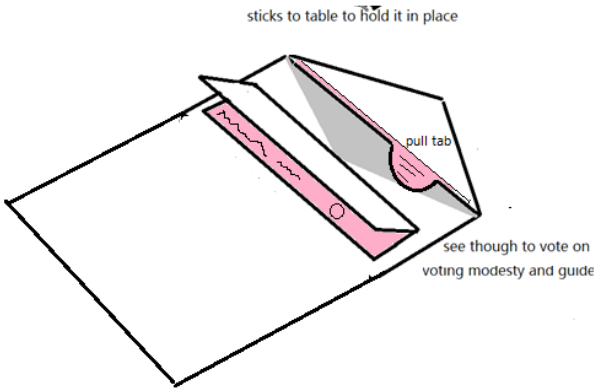

Figure 4. An example of unfolding envelope. The top unfolds up to partially cover what the voter is looking at.

focusing on from people in the same room, as is shown on Figure 4.

Sticking envelopes.
The bottom of the envelope could be made of removable adhesive. In conjunction with the previous methods, this could increase physical stability while marking a ballot, especially for voters with limited fine motor control.

Ballot improvements

One race per sheet.
A single race per sheet of paper makes the selections concrete and might reduce accuracy problems. This can be done by having each separate race on a different card (recto only), making the mail-in ballot an envelope containing a stack of cards. It is also possible to fold a single sheet of paper – potentially with differently sized folds – with a single race per fold to keep the ballot organised and reduce waste of separate cards. However, it is likely that making each race the same length of paper in folds would be simpler and easier to handle. The problem for this approach is the possibility of a coercing agent later replacing part of the cards with fraudulently marked cards.

Tabs.
Indexing tabs on top of each card could help voters navigate the different races. Each card would have a protruding tab, with the summary of the race (like "Presidential" or "Sheriff") indicated on it. Depending on the number of races, there could be multiple layers of tabs. The tabs could also be on the side of the ballot instead of the top/bottom. This is compatible with folded ballots but might not be easily adaptable to the ballot holder or scanner systems [20].

Stickers.
Adhesive stickers can be used to both control for overvoting and undervoting — and to eliminate the need for a marking device. One option is to have a sheet of stickers distributed with the ballot (or integrated with the ballot, e.g. on the side margins), such that voters unpeel them one at a time, and then stick them in front of the candidate of their choice on the appropriate race. This allows the voter to see where and how many selections are available at all times. The stickers should be easy to peel off their initial sheet — a star-like shape for example, has more corners that can be easily peeled up than an oval[13] — without being removable from the ballot without visibly damaging the paper.

The stickers can be laid out on the corresponding tabs, as a memory aid. This way, voters can see at a glance (or feel) which races they have yet to vote on. An example of how to add this to an already existing ballot is shown on Figure 3. In this case, margins on each side of the ballot include indications of where races begin and end with stickers associated with each. The margins can be easily be designed to pull off as a sticker or tear off on perforations. A simple review of the stickers on the side shows the voter what races have been voted and adds a separate way of seeing if a sticker has been tampered with.

Another option would be to print the ballot on a two layer paper; with the top layer being a sticker that can be removed from the bottom layer. The ballot is printed so that each sticker is printed adjacent to the corresponding race, with as many stickers as allowed selections for that race. The voters peel one off for each race, and sticks it next to the candidate of their choice.

The voter can remove the margins with unused stickers or put any unused sticker in a designated place at the end of the ballot to ensure that any undervote is intentional[14].

Stickers can be made compatible with write-in candidates in multiple ways, the simplest corresponding to leaving space: for the candidate's name, and for the sticker next to it (to ensure that all stickers are used).

More usable ballots for visually impaired people.
The sticker approach could be designed to allow a non-sighted voter to find their way around an ballot. The voter would still have to have the ballot read by a camera OCR or person, but could feel where overlays are and where stickers are as they commit to selections. [15]

Off-the-shelf text-to-speech applications on phones that can be used to scan the ballot and read on private earphones what is viewed by the camera could suffice to list the candidates in order (after which the voter could put a sticker on the corresponding dent). This scan could be made relatively secure thanks to multiple considerations: there are multiple potential applications that could be used, all of them could be audited continuously during the vote — including by friends of the voter to check that it works correctly before the vote happens. Changing the names or order of candidates would also require non-trivial modifications, as it would only be interesting to do so when certain geographical or political conditions are true (to give a party a statistical advantage).

Although reading in braille is not an option for most visually impaired voters, finding a few dents or cuts in the paper should be. By using appropriate markings for the sliding ballot holder, it should then be possible to only show one race at a time. Making an X cut in the ballot to indicate where to put the sticker could improve general usability, while keeping costs low as it could be

[13] The physical nature of this adds a visible indicator of which races have and haven't been marked. It also creates something akin to gamification which could increase voter engagement.

[14] Extra stickers that weren't initially with the ballot showing up when it is counted present evidence that it was doctored, by adding stickers after the ballot was deposited. This scheme for showing when a ballot has been altered reduces the available options for spoiling a ballot.

[15] Braille ballots have been made available in certain places in the USA, but this is not a fully accessible solution, as only some 10% of visually impaired people have the ability to read it, and it could increase error rates in any case [15].

naturally integrated in the sticker cutting phase. This X can be felt by the voter, and could improve security by making it harder to remove with tearing the paper.

Ballot correction mechanisms.
One common issue with mail-in ballots is that if it is possible to correct mistakes, then, a ballot intercepted en route (or within the household) could be modified. On the other hand, if the decisions made are, as they should be, non-modifiable (for example with unpeelable stickers), any mistake requires the voter to spoil (void) their ballot, and obtain a new one. This always complexifies the ballot distribution process and might prevent certain people from voting due to problems getting the replacement ballot.

Ballots might be initially modifiable, but to add a way to make the ballot non-modifiable once the voter is satisfied. For example, a fully transparent adhesive sheet could be pasted onto the ballot to prevent further modifications, as is sometimes done on cheques with cellophane tape such as sellotape.

Finally, if stickers are used, a small number of duplicate stickers could be added in tandem with cover-up "undo" stickers that would void whatever sticker was underneath, allowing the voter to put a second sticker on that same race without it counting as an overvote. One approach to this, in the case of a ballot entirely printed on a sticker sheet, is to have a composite sticker that has a couple "undo" stickers within its perimeter; if one or more of these are used, the composite sticker will be missing those. The composite sticker is used to seal the ballot and reveal how many cover-up stickers were used before the ballot was sealed. This makes it clear that the voter put the undo stickers on while voting. This system will let people correct mistakes without spoiling their ballot.

Chain of custody improvements

Envelope tracking.
Making sure that the envelope gets safely from the — legitimate — voter to the ballot box (or the polling office) is the first priority for the chain of custody for the marked ballots. This must be done without breaching the voter's privacy.

The simplest case uses our stickers as seal; the composite sticker seal and a signature across the closure flap makes tampering with the ballot evident if the seal is torn. In this case, the closure flap also covers any slide through race viewing slot. The race viewing slot modesty panel is folded down with the envelope closure as well.

Another option is to have two return envelopes one inside another. The first envelope bears the name of the voter and is signed by them. Once at the polling office, the officials receive that envelope, check that the voter hasn't voted yet and is on the voter rolls, and then opens it before casting the envelope inside into the ballot box. This is a known practice that is used in various forms in some voting systems, although not always with the security of a second envelope. Similar features can be implemented in a variety of ways.

To reassure voters that their ballot arrived safely, voters might apply at any point before the vote for a pair of linked scratch-off tickets with unique numbers. They scratch the same digit on both tickets to check that they are indeed identical, and then put one inside their envelope. When the envelopes arrive at the polling office, the ballots are cast in a ballot box, and the tickets in another, to de-correlate them. The tickets are then scratched and checked, and the numbers printed online (or shown at city hall). Inspired by systems already in place in countries like Portugal or Romania [24], incentives can be made for such statistical ballot authenticity verification by offering some lottery with the tickets (and a special prize if someone shows an inconsistency).

Identifiable ballots.
One issue that regularly comes up in recounts is that each subsequent recount finds slightly different totals for each candidate. One method to improve the counting accuracy and eliminate potential avenues for fraud would be to make the ballots identifiable. Some ballots do come with serial numbers. Another approach is not to make ballots identifiable when they are being filled (as it would break the privacy of the voter) but when they are first taken out of the ballot box. A numbering stamp would add a serial number for the purpose. This would make errors easier to track during audits and recounts.

Attributable recounts.
An alternative post-vote ballot identification is for the person counting the ballots to also be identifiable, for example by having a specific numbering stamp (with a different pattern for each person). This could be useful in hand recounts or in jurisdictions where initial counting is done by hand. This improves the security of the chain of evidence but it also makes it easier to find out who miscounted in which way. Proper security must be included to prevent it from being used for disciplinary purposes by a powerful adversary in a sufficiently corrupt system.

DISCUSSION

The ideas shown here are proposals that can be Inexpensively tested and implemneted. While we have made prototypes of them, they still need empirical studies to validate their usability, resistance to adding confusion or errors, and ease of production. The CoViD-19 pandemic made in-person studies harder to organise, but at the same time, the potential massive deployment of mail-in voting in the intermediate future also makes those improvements all the more critical, as existing voting protocols might be too impractical not to make changes, even if change seems difficult. As voting officials are often a major part of practical experimentation on such procedures [3], we encourage anyone interested to communicate with the authors for any experimental engagements.

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